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The nutritive value of corn oil meal and feather protein

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THE NUTRITIVE VALUE OF CORN OIL MEAL
AND FEATHER PROTEIN

by

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INTRODUCTION

The proteins, as one of the primary groups of nutrients, have commanded the attention of research workers for many years. Although results of their experiments have demonstrated that various proteins differ greatly in their nutritive value, knowledge in this field is still incomplete. Since a large portion of the animal diet must be compounded from high quality protein feeds, which are usually high priced, it is important that this nutrient group be utilized as efficiently as possible.

The first part of this investigation was conducted to obtain experimental results on the nutritive value of corn oil meal protein, and the second part on the nutritive value of feather protein.

Corn Oil Meal

Corn oil meal is an important corn milling by-product that has been produced on a commercial scale since the beginning of the twentieth century. It consists of the corn germ after the oil has been extracted and it contains from 20 to 25 percent protein.

When the starch, glucose and hominy industries first developed on a commercial scale, the unextracted corn germ was disposed of by adding it to feed products. However, as the demand for vegetable oils increased, it became profitable to expel the oil from the corn germ. Thus, corn oil meal replaced the corn germs as a by-product of the corn milling industry.

Because starch alone is required in more than thirty modern industries, the business of separating it from the corn kernel is a very important industry. At least fourteen large plants are now operating in the United States processing from 60,000,000 to 80,000,000 bushels of shelled corn each year. This means that from 65,000 to 85,000 tons of corn oil meal are available annually as a by-product of the starch industry. Since experimental results involving the feeding value of corn oil meal are inconclusive, it seemed advisable to determine some of the qualities of this product.

Feather Protein

Many thousand tons of feathers are available each year in the United States as a by-product of the poultry meat industry. Some are used for industrial purposes, but several thousand tons remain unused.

Block (4) analyzed hens' feathers and found them to contain large amounts of glycine, cystine, arginine, phenylalanine, and lysine. Experimental results of Rose (20), Almquist (1), and Hegsted, et al (9) (10) indicate, that with the possible exception of cystine, these amino acids are indispensible in the diet of the rat or chick.

Since Goddard and Michaelis (7) demonstrated that chemically treated feather protein is digested by pepsin and trypsin in vitro and since feathers offer a potential source of valuable protein feed, it seemed advisable to investigate the nutritive value of treated feather protein.

REVIEW OF LITERATURE

Corn Oil Meal

An analysis of corn oil meal was reported by Moser (17) as early as 1867. Since that time many analyses have been made which show that corn oil meal has the following approximate percent composition: Protein, 23.0; nitrogen-free extract, 53.0; fat, 6.0; ash, 2.0; fiber, 7.0; and moisture, 9.0.

As early as 1894 Voorehees (26) reported the results of an experiment in which a diet containing a large amount of corn oil meal was fed to one lot of two animals. He did not state the kind of animals used, but the type of diet indicates they were cattle. He found that corn oil meal was absolutely refused by one animal, but after being disguised by mixing with other ingredients of the diet, was eagerly eaten by the other. He concluded that, "Corn oil cake is very rich in fat and should not be fed in excessive amounts."

In 1903 Lindsey (14) determined the digestion coefficient for sheep of a mixture of 250 grams of corn oil meal and 700 grams of English hay (mostly _Poa protensis_). He reports the following digestion coefficients for the corn oil meal diet as a percentage: dry matter, 79.82; protein, 69.11; fiber, 94.90; nitrogen-free extract, 86.66 and fat, 96.66.

Mussehl and Ackerson (18) carried on one experiment in which the nutritive value of corn oil meal in the diet of the chick was compared with corn gluten feed and corn gluten meal. All diets contained exactly the same percent of protein. Their results indicated that corn oil meal was not as valuable for growing chicks as either of the other two products. They did not determine whether the results obtained on the corn oil meal diet were due to poor palatability or to a low nutritive value. Later Mussehl (19) replaced 10 percent of the corn meal in the diet of the chick with corn oil meal fresh from the manufacturer and obtained a satisfactory growth rate. He also found this ration to be palatable. However, Nebraska workers found commercial corn oil meal to be rather variable in its growth promoting properties. From the results of a very limited number of experiments they concluded that 20 percent of the chick diet can be compounded from corn oil meal provided the product is strictly fresh when fed.

A few reports have been published on the feeding of corn germ meal to animals. Corn germ meal differs from corn oil meal in that it contains a greater percentage of oil. As the two products are similar some idea of the nutritive value of the former may be obtained from experimental results using the latter.

McCollum, et al. (16) made several attempts to nourish young rats on a diet consisting solely of corn germ and mixtures of corn germ and whole ground corn in several proportions. Their attempts were uniformly unsuccessful. All rats placed on these diets died in approximately three weeks.

These results were contrary to the findings of Caserio (6) who stated, "Maize germ and its ethereal extract have no toxic properties, but on the contrary show favorable somatic effects."

Experiments conducted by Boruttau (5), on man and animals with a corn germ preparation indicate that the utilization of nitrogen of this product corresponds to that of meat. Increased growth was observed in young dogs, rabbits, and mice when fed this product.

Keratin Protein

No research, of which the author is aware, has been conducted involving the feeding of feather protein in the animal diet.

Block (4) reported the following percentages for the composition of hen feathers: nitrogen, 15.5; sulphur, 2.3; glycine, 9.5; cystine, 6.8; arginine, 6.0; phenylalanine, 5.3; tyrosine, 2.2; lysine, 1.6; tryptophane, 0.7; and histidine, 0.3.

As early as 1877 Kuhne (13) reported that the keratin of hair was made digestible by pepsin when the surface area was increased by mechanical means.

It has been demonstrated by Goddard and Michaelis (7) that feather protein can be rendered digestible by pepsin and trypsin, in vitro, after treatment with thioglycolic acid, potassium cyanide or sodium sulfide in an alkaline solution. They state, "The effect is chiefly due to the splitting of the disulfide groups, which are essential for the maintenance of the fibrous structure of keratin." The chemically treated feathers were soluble in alkali or acid, had a definite isoelectric point and were digestible by pepsin and trypsin.

Waldschmidt-Leitz and Schuchmann (27) and Stay (25) have also observed enzymatic digestion of wool and hair after treatment with oxidizing or reducing agents.

Routh and Lewis (21) observed that powdered wool was digested by both trypsin and pepsin, in vitro. Later Routh (22) found that a water extract of powdered wool contained considerable nitrogen, which increased rapidly as the time of grinding was prolonged. He also found that the physical change in the wool, due to grinding, was accompanied by oxidative changes.

Blaschko (3) included keratin protein (sheep horn) in the diet of man and sheep and observed its effect on growth of hair and wool. In his first experiment he had his hair and beard cut to 3 millimeters in length. Then, after four weeks on an ordinary (not excessive) protein diet, repeated the procedure and found that he had produced 5 milligrams of hair. During the second four-week period he supplemented the same diet with a daily dose of 1.5 grams of hydrolized horn. This resulted in the production of 6.3 milligrams of hair. Continuance of the same procedure during the third four-weeks resulted in the production of 9.2 milligrams of hair.

In his second experiment he fed two sheep on an ordinary diet and two on a portion of the same diet supplemented with a daily dose of 10 to 15 grams of hydrolized horn. After two and one-half months on these diets, the wool fibers of the sheep fed the supplemented diet measured 8.15 microns in width as compared to 6.9 microns for the control. Blaschko stated, "If one assumes that the fibers increased in length and weight in the same proportion and then give the control sheep a value of one, the sheep fed the hydrolized horn would have a value of 1.74." Since actual measurements were not taken on weight of fleece and length of wool fiber, the above statement is possibly open to question. Zunts (29) found that hydrolized horn preparations had therapeutic value. In some cases the feeding of this preparation caused complete restoration of the hair while in others it failed.

Very recently Routh (23) reported, "that rats fed unsupplemented powdered wool as their sole source of protein lost weight less rapidly and lived longer than controls on a nitrogen-free diet." He found that the addition of tryptophane, methionine, histidine or lysine to the powdered wool diet resulted in a moderate rate of growth.

EXPERIMENTAL

Plan of Investigation

The plan of this investigation was to feed to Single Comb White Leghorn chicks and rats a cereal basal diet believed to be complete in the known nutrients except quantity of protein. This diet produced a slow rate of growth but no other evidence of deficiency. Corn oil meal[1/], feather protein and various combinations of these products with other high nitrogen feeds were added to the cereal basal in order to evaluate their nutritive properties. In some experiments, both chicks and rats were used because of a possible difference in the nutritive value of these products for different species. Gain in body weight and feed efficiency were used to measure the nutritive values of the various diets. Weights, feed consumption, mortality and observations of general health were recorded at suitable intervals.

Most of the data were analyzed statistically.

Materials

Chick experiments

Most of the chick feeding experiments were conducted in a stationary brooder house in which the room temperature and humidity were regulated by

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1/ The corn oil meal was supplied through the courtesy of Dr. H. H. Schopmeyer, American Maize-Products Co., Roby, Indiana.

thermostatic control. Large automatic fans drew out the humid air when the relative humidity went above 40 percent as indicated by a psychrometer. During the cold months the room temperature was maintained at 70°F. by a hot air heating system. All experiments were conducted in electric batteries which had ample space for the chicks placed in them. The amount of light was kept as uniform as possible by placing electric lamps at all necessary points.

Most of the chicks used in this investigation were hatched from eggs obtained from mass-mated flocks at the Iowa State College Poultry Farm. The eggs were incubated at the college hatchery. For a few experiments the chicks were obtained from a commercial hatchery.

Rat experiments

These experiments were conducted in the Physiological Chemistry laboratory. The rats were placed in wire bottom cages which were equipped with suitable feed and water containers. All experimental rats were obtained from the laboratory stock colony.

Experimental Procedure and Results

General procedure

Chick experiments Except where otherwise noted the procedure was as follows: The diets were prepared by first mixing the cereal basal described in Table 1. This basal mixture was then mixed with the ingredients listed in Table 1 to make the experimental diets which were fed ad libitum for an eight week period. The diets were compounded to contain 1.0 percent calcium, 0.6 percent phosphorus and from 8 to 16 percent protein as the need arose. The fiber content of the diets fed in each experiment was adjusted to approximately the same level, by adding finely ground sawdust to the low-fiber diets. The percentages of calcium, phosphorus and protein in the diets were verified by chemical analysis.1/

Sufficient cod liver oil was hand mixed with approximately each ten pounds of feed consumed to insure an adequate level of vitamins A and D. Sufficient riboflavin concentrate2/ was compounded in the diet to insure an adequate amount of this vitamin. The manganese sulphate was placed in solution and then dried on the wheat bran of the diet prior to mixing. The chicks were started on experimental rations when one day old.

Every precaution was used to prevent wastage of feed. This was accomplished, mainly, by the frequent additions of small amounts of feed and by the use of inch mesh wire placed on top of the feed in each pan.

The day-old chicks were wing banded and placed in comparable pens of battery brooders. To insure a randomized distribution, the bands were thoroughly mixed prior to the banding operation. After banding the lots were made up by placing the desired number of chicks with consecutive band numbers in the same pen. Any lot of chicks and the diet fed to that lot were identified by assigning the same number to both. Additional lots receiving the same diet were identified by adding letters of the alphabet to the diet number.

1/ Most analyses were made through the courtesy of Dr. H. H. Schopmeyer, American-Maize Products Company, Roby, Indiana, and Mr. M. Rhian, Agr. Exp. Sta., State College of Washington, Pullman, Washington.

2/ Labco-lactoflavin.

TABLE 1.

PERCENTAGE OF INGREDIENTS IN THE DIETS

Composition of Cereal Basal and Test Diets

Feeds	Cereal Basal	Test Diet
Ground yellow corn	16.67	
Ground oats	40.00	
Wheat bran	16.67	
Wheat middlings	16.67	
Alfalfa meal	8.33	
Salt	1.66	
Cereal basal		60.0-70.0*
Cod liver oil (400 A. O. A. C. chick units per gram)		0.25
Riboflavin supplement		0.66
Protein supplement		A#
Carbohydrate supplement		B/
Calcium supplement		C/
Phosphorus supplement		D/
Total	100.00	100.00

* Enough cereal basal used to furnish 8.0 percent crude protein.

\# A sufficient amount of protein supplement added to furnish from 3 to 8 percent crude protein.

/ These variables were used to adjust the total diet to 1.0 percent calcium and 0.6 percent phosphorus.

Body weights and feed consumption data were recorded at bi-weekly intervals. Observations of any abnormalities and mortality were also recorded.

Most chicks that died during the experimental period were autopsied by the Veterinary Department.

Rat experiments The rats used in this investigation were placed on experimental diets at weaning time (26 to 28 days of age) and weighed approximately 50 grams.

The diets were fed for a ten week experimental period. Weights and feed consumption data were recorded at weekly intervals.

The protein and riboflavin content of corn oil meal

Procedure This experiment may be considered as a preliminary trial conducted to evaluate the quality of the protein and the riboflavin content of corn oil meal. A control diet containing good quality protein was compared with an unsupplemented and riboflavin supplemented corn oil meal diet at the same protein level. The control diet had produced normal growth in previous experiments. The diets fed are described in Table 2 and the method of procedure was the same as that described under the general heading.

Results The rates of gain in weight, feed efficiency and mortality for chicks and rats fed three different diets are summarized in Tables 3 and 4.

Because of the relatively small number of animals completing the experiment in the corn oil meal lots, no attempt was made to analyze the data

TABLE 2.

PERCENTAGE OF INGREDIENTS IN THE DIETS

Protein & Riboflavin Study*

Feeds[x]	Lot numbers 1 1A	2 2A	3 3A
Ground yellow corn	29.35		
Ground oats	32.00	25.00	23.34
Wheat bran	10.00	10.00	10.00
Wheat middlings	10.00	10.00	10.00
Alfalfa meal	5.00	5.00	5.00
Salt	1.00	1.00	1.00
Corn oil meal		45.00	46.00
Meat and bone meal	3.00		
Herring fish meal	3.00		
Soybean oil meal	2.40		
Dry skim milk	3.00		
Lactoflavin			0.66
Cod liver oil	0.25	0.25	0.25
Ground oyster shell	1.00	0.25	0.25
Steamed bone meal		3.50	3.50
Total	100.00	100.00	100.00

* All diets adjusted to 16 percent protein.

x 0.2 of an ounce of manganese sulphate added per 100 pounds of mash.

TABLE 3.

THE VALUE OF CORN OIL MEAL AND CORN OIL MEAL PLUS RIBOFLAVIN AS A SUPPLEMENT TO A CEREAL CHICK DIET

Diet	Lot*	Ave. gain in wt.		Ave. feed consumption		Feed efficiency¤		Mortality
		By lots	By diets	By lots	By diets	By lots	By diets	By lots
	No.	Gms.	Gms.	Gms.	Gms.			No.
	1	507		1827		3.6		0
Control	1a	526	516	1858	1846	3.5	3.5	0
	2	78		610		7.8		7
Corn oil meal	2a	85	81	688	649	8.1	7.9	5
Corn oil meal	3	79		561		7.1		4
plus riboflavin	3a	106	92	628	595	5.9	6.5	9

* 15 chicks started in each lot.

¤ Expressed as grams of feed required to produce a gram of gain.

TABLE 4.

THE VALUE OF CORN OIL MEAL AND CORN OIL MEAL PLUS RIBOFLAVIN AS A SUPPLEMENT TO A CEREAL RAT DIET

Diet	Lot*	Ave. gain in wt.	Ave. feed consumption	Feed efficiency	Mortality
		By lots	By lots	By lots	By lots
	No.	Gms.	Gms.		No.
Control	1	195	1068	5.5	1
Corn oil meal	2	100	722	7.2	5
Corn oil meal plus riboflavin	3	109	762	7.0	0

* 10 rats started in each lot.

statistically. However, an examination of the data suggests the following conclusions: Both chicks and rats fed the unsupplemented corn oil meal diet grew at a very slow rate, utilized their feed very inefficiently and suffered a high mortality. Supplementing the corn oil meal ration with riboflavin was of very questionable value. It is interesting to note that the feed consumption and gain in body weight of the chicks fed the corn oil meal diets were approximately one-third and one-sixth, respectively, of the same figures for chicks fed the proven diet. Since this relationship does not hold for rats, it appears that the nutritive value of corn oil meal is not the same for these species.

Palatability of corn oil meal

Procedure Since the preliminary experiment demonstrated that the addition of 7 percent crude protein from corn oil meal to the cereal basal produced only a very slow rate of growth, it seemed advisable to determine whether the poor growth was due to poor palatability or quality of the protein in corn oil meal. Therefore, a further experiment was designed to obtain information on the palatability of chick diets containing various quantities of corn oil meal.

The various diets were compounded to contain 13.0, 21.5, 30.0 and 34.0 percent, by weight, of corn oil meal. These amounts corresponds to 3, 5, 7 and 8 percent supplementary protein respectively. The control diet previously used was modified to compare with the corn oil meal diet at each of the above mentioned protein levels. The composition of the diets is described in Table 5. The procedure was the same as that described under the general heading.

Results The results of this experiment are summarized in Table 6. In order to more clearly show the results, the tabulated data in this table on average gain in body weight and feed consumption are presented on a horizontal bar graph in Plate 1.

The analysis of variance and co-variance tests of Snedecor (24) on data obtained in this experiment on the corn oil meal diets seems to justify the following conclusions: 1. There are highly significant differences among the diets for gains in body weight and amounts of feed consumed. 2. The regression of gain on feed intake is highly significant for "between diets", thus the amount of feed consumed is definitely influenced by the kind of diet. 3. However, after all gains have been adjusted to a common food intake, highly significant differences still exist, demonstrating that there are marked differences in quality of the diets. Calculation of the least significant difference revealed that the feed consumption did not differ significantly when 13.0, 21.5 or 30.0 percent of corn oil meal was compounded in the diet; however, the consumption of a diet containing 34 percent corn oil meal was significantly lower than that of diets containing 21.5 or 30.0 percent of this product.

The graph given in Plate 1 shows the trend of feed consumption quite clearly. Examination of this graph shows that the average feed consumption of the chicks fed a diet containing 30.0 percent corn oil meal was slightly below that of the chicks fed a diet containing 21.5 percent of this product.

TABLE 5.

PERCENTAGE OF INGREDIENTS IN THE DIETS

Palatability Study*

Feeds#	Lot Numbers									
	Cereal Basal	4 4A	5 5A	6 6A	7 7A	8 8A	9 9A	10 10A	11 11A	12 12A
Ground yellow corn	16.67									
Ground oats	40.00									
Wheat bran	16.67									
Wheat middlings	16.67									
Alfalfa meal	8.33									
Salt	1.66									
Cereal basal		62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40
Corn oil meal			34.00		30.00		21.50		13.00	
Meat & bone meal		4.00		3.60		2.60		1.50		
Herring fish meal		2.90		2.60		1.80		1.10		
Soybean oil meal		4.20		3.70		2.65		1.60		
Dry skim milk		6.00		5.00		3.60		2.10		
Sugar		15.73	0.14	18.06	3.78	22.01	11.51	25.72	19.25	31.08
Riboflavin supplement		0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Cod liver oil		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calcium carbonate		0.80	1.30	1.00	1.30	1.10	1.30	1.20	1.30	1.30
Di-calcium phosphate			1.25		1.25	0.10	1.25	0.55	1.25	1.25
Fiber		3.06		2.73	0.36	2.83	1.13	2.92	1.89	3.06
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* The protein content of the various lots was as follows: lots 4 and 5, 16%; lots 6 and 7, 15%; lots 8 and 9, 13%; lots 10 and 11, 11%; and lot 12, 8%.

\# 0.2 of an ounce of manganese sulphate added per 100 pounds of mash.

TABLE 6.

THE EFFECT OF VARIOUS AMOUNTS OF CORN OIL MEAL ON FEED CONSUMPTION AND GROWTH OF CHICKS

Lot*	Protein level	Amount of corn oil meal in the diet	Protein supplement	Average gain in weight By lots	Average gain in weight By diets	Comparative gain By protein level	Average feed consumption By lots	Average feed consumption By diets	Comparative feed consumption By protein level	Feed efficiency By diets	Mortality By diets
No.	%	%		Gms.	Gms.	%	Gms.	Gms.	%		No.
4			Standard	632			2001				0
4a	16	0.0	mixture	628	630	100	2005	2003	100	3.2	0
5			Corn oil	230			1177				3
5a	16	34.0	meal	240	235	37	1191	1184	59	5.0	4
6			Standard	588			1874				0
6a	15	0.0	mixture	591	590	100	1899	1887	100	3.2	0
7			Corn oil	323			1323				0
7a	15	30.0	meal	330	317	55	1338	1331	71	4.1	1
8			Standard	456			1669				0
8a	13	0.0	mixture	450	453	100	1592	1631	100	3.6	0
9			Corn oil	317			1429				1
9a	13	21.5	meal	310	314	69	1359	1394	85	4.4	1
10			Standard	410			1499				0
10a	11	0.0	mixture	437	424	100	1585	1542	100	3.6	1
11			Corn oil	274			1349				1
11a	11	13.0	meal	265	270	64	1223	1286	83	4.8	0
12				137			729				0
12a	8	0.0	Cereal	152	145	-	755	742	-	5.1	1
Least significant difference for corn oil meal diets				18			145				

* 15 chicks started in each lot.

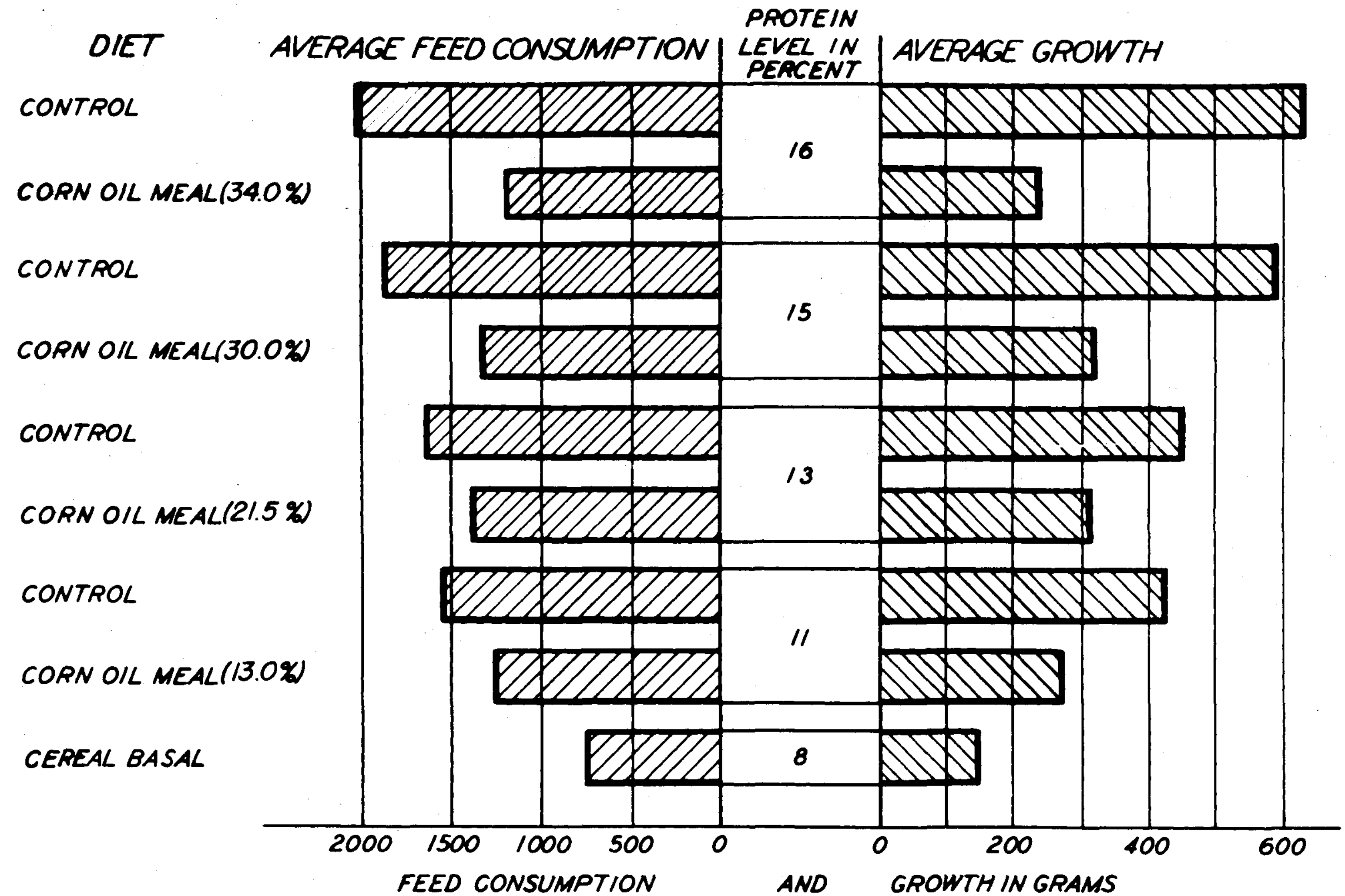

PLATE I. THE EFFECT OF VARIOUS AMOUNTS OF CORN OIL MEAL ON FEED CONSUMPTION AND GROWTH

Although this difference is not significant it indicates a trend which becomes significant when 34.0 percent corn oil meal was compounded into the diet.

The rate of gain and feed consumption of the chicks fed the 16 percent corn oil meal diet were higher than that obtained in the first experiment (Table 3) for a similar diet. This can be explained by the fact that in the preliminary experiment the total dietary protein was adjusted by altering the amount of ground corn and corn oil meal, making it necessary to include 45.0 percent of corn oil meal in the diet. In the latter experiment the adjustment was made by using sugar as a cource of carbohydrate which resulted in the inclusion of only 34.0 percent of corn oil meal in the diet.

Amino acid deficiencies of corn oil meal[1/]

Since the previous experiment showed marked differences in the quality of the diets containing various amounts of corn oil meal, an investigation was planned to determine whether corn oil meal was deficient in certain selected amino acids. The diets described in Table 7 were fed according to the following methods:

Group feeding method; Procedure This experiment was undertaken to obtain information about a possible deficiency of histidine, tryptophane, glycine, lysine, glutamic acid, cystine or arginine in the corn oil meal diet described in Table 7. These amino acids were selected after comparing

1/ The materials for this and two other experiments were made available through the courtesy of the Poultry Division of the Agr. Exp. Sta., State College of Washington, Pullman, Washington.

TABLE 7.

PERCENTAGE OF INGREDIENTS IN THE DIETS

Corn Oil Meal Amino Acid Deficiency Study*

Feeds#		Lot Numbers							
		13	14	15	16	17	18	19	20
	Cereal basal	13A-Z 13A1-F1				17A-H	18A-H	19A-H	20A-H
Ground yellow corn	16.67								
Ground oats	40.00								
Wheat bran	16.67								
Wheat middlings	16.67								
Alfalfa meal	8.33								
Salt	1.66								
Cereal basal		62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40
Corn oil meal		30.00	25.80	27.80	27.50	27.00	28.00	28.00	28.00
Sugar		4.14	7.23	5.54	5.69	6.28	5.36	5.22	5.18
Riboflavin supplement		0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Cod liver oil		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calcium carbonate		1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Di-calcium phosphate		1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Fiber			0.38	0.20	0.23	0.26	0.18	0.18	0.18
Histidine monohydrochloride			0.73						
Tryptophane				0.60					
Arginine monohydrochloride					0.72/				
Glycine						0.60			
Cystine							0.60		
Glutamic acid monohydrate								0.74/	
Lysine monohydrochloride									0.78/
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* All diets adjusted to 15 percent protein.

\# 0.2 of an ounce of manganese sulphate added per 100 pounds of mash.

/ Equal to 0.6 percent pure amino acid.

the amino acid content of chicken flesh, feathers and corn oil meal with the amino acid requirements of the chick as generally accepted in the literature.

In this experiment a large number of day-old cockerels were placed on the corn oil meal diet described in Table 7 for a three week period. Chicks were selected for a 14 day (approximate) experimental period on the basis of present weight, past rate of gain and condition. The lots were made up as follows: The cockerels were divided into ten outcome groups, placing in each eight cockerels thought to have the same gaining ability. Then one cockerel from every outcome group was randomly assigned to each of the eight diets. This method of making up the experimental lots aided in insuring a balance of high and low gainers in each lot and, at the same time, insured a random distribution because all cockerels in any outcome group had the same chance of being assigned to a particular diet.

The principle of paired feeding was employed. In this case the feed consumption among the various lots was equalized by weighing in the same amount of feed to every lot each morning. The amount was determined by the lot that ate the least on the previous day.

All chicks were weighed at the beginning and termination of the experimental period on two consecutive days as a precautionary measure against weighing fill instead of actual gain. Weights were also taken at the end of the first week.

<u>Group feeding method</u>; <u>Results</u> Table 8 summarizes the results of an experiment in which the corn oil meal diet described in Table 7 was supple-

mented with several amino acids.

Calculation of the least significant difference revealed that the addition of cystine and lysine to a corn oil meal diet produced a rate of gain which was significantly greater than that produced by the unsupplemented diet. Also, the addition of glycine and glutamic acid produced a gain just below the point of significance. The addition of histidine, tryptophane and arginine to the corn oil meal diets did not increase the gain. Examination of Table 8 clearly shows that, under the conditions of this experiment, chicks respond readily to the addition of some amino acids and not to the addition of others.

No mortality occurred in this experiment.

Paired feeding method; Procedure This experiment was designed to obtain additional information on the deficiency of cystine, lysine, glycine, and glutamic acid in the corn oil meal diet described in Table 7.

From one to three weeks of age the cockerels were fed as described under the group feeding method. Eight pairs of cockerels were used to compare the nutritive value of diet number 13, Table 7 with each of the diets numbers 17, 18, 19 and 20, Table 7. One cockerel of each pair received the unsupplemented diet and the other the diet containing an added amino acid. Each cockerel in a pair weighed the same at the beginning of the experimental period and they were, as near as possible, alike in all ways. They were kept in individual pens and fed weighted amounts of their respective diets. The food intake was controlled so that the two cockerels of any pair received, as nearly as possible, the same amount of feed, determined by the

TABLE 8.

THE VALUE OF SELECTED AMINO ACIDS AS A SUPPLEMENT TO A CORN OIL MEAL DIET*

Supplement	Lot	Ave. initial wt.	Ave. final wt.	Ave. gain	Gain over unsupplemented diet	Feed efficiency
	No.	Gms.	Gms.	Gms.	Gms.	
Corn oil meal	13	125.6	220.7	95.1	-	4.4
Corn oil meal plus histidine	14	125.6	221.3	95.7	0.6	4.4
Corn oil meal plus trytpohane	15	126.6	226.4	99.8	4.7	4.2
Corn oil meal plus glycine	16	125.6	232.9	107.3	12.2	3.9
Corn oil meal plus lysine	17	125.8	236.6	110.8	15.7	3.8
Corn oil meal plus glutamic acid	18	126.2	232.3	106.1	11.0	4.0
Corn oil meal plus cystine	19	125.6	241.1	115.5	20.4	3.7
Corn oil meal plus arginine	20	126.0	222.3	96.3	1.2	4.4
Least significant difference				12.9		

* Each lot of chicks consumed 4230 grams of feed during the 16 day experimental period.

cockerel consuming the least amount. The weights were taken as described under the group feeding method.

Paired feeding method; Results Additional information on the value of adding cystine, lysine, glycine and glutamic acid to the corn oil meal diet described in Table 7 as determined by the paired feeding method, is given in Tables 9 through 12. All diets were fed for a 13 day experimental period. An analysis of variance test showed a highly significant difference in the rate of body gain when the corn oil meal diet was supplemented with cystine, a significant difference when lysine and glutamic acid were added, and no significant difference when glycine was added. The results obtained from both feeding methods seem to justify the conclusion that the corn oil meal diet employed was deficient in cystine and lysine; also, that the addition of glycine did not increase the rate of body gain significantly. In the group feeding method, supplementing the corn oil meal diet with glutamic acid produced a rate of gain just short of that required for significance. In the paired feeding method, the gain was just above the amount required for significance. The slightly different results obtained may be due to increased precision in the second method since eight replicates were used. The position of glutamic acid is possibly a border line case. Additional research is necessary before any definite conclusions can be made on the possible deficiency of glutamic acid in the corn oil meal diet used.

TABLE 9.

THE VALUE OF GLYCINE AS A SUPPLEMENT TO A CORN OIL MEAL DIET

	Pair 1		Pair 2		Pair 3		Pair 4		Pair 5		Pair 6		Pair 7		Pair 8	
	Con-*trol	Gly-#cine	Con-trol	Gly-cine	Con-trol	Gly-cine	Con-trol	Gly-cine	Con-trol	Gly-cine	Con-trol	Gly-cine	Con-trol	Gly-cine	Con-trol	Gly-cine
Initial Wt. gms.	122	122	122	122	120	120	120	120	118	118	116	116	116	116	114	114
Final Wt. gms.	199	201	204	203	201	209	193	193	193	194	202	192	194	196	188	189
Gain gms.	77	79	82	81	81	89	73	73	75	76	86	86	78	80	74	75
Total food gms.	238	236	355	355	342	240	304	308	304	301	350	350	334	336	256	256
Gain over control/ gms.		2		-1		8		0		1		0		2		1

* Diet Number 13

\# Diet Number 17

/ Average gain over control 1.6 grams; gain required for least significant difference 2.3 grams.

TABLE 10.

THE VALUE OF CYSTINE AS A SUPPLEMENT TO A CORN OIL MEAL DIET

	Pair 1		Pair 2		Pair 3		Pair 4		Pair 5		Pair 6		Pair 7		Pair 8	
	Con-* trol	Gly-# cine	Con- trol	Gly- cine	Con- trol	Gly- cine	Con- trol	Gly- cine	Con- trol	Gly- cine	Con- trol	Gly- cine	Con- trol	Gly- cine	Con- trol	Gly- cine
Initial Wt. gms.	122	122	122	122	120	120	120	120	120	120	118	118	118	118	116	116
Final Wt. gms.	200	218	202	210	175	183	196	204	198	202	196	206	200	201	188	200
Gain gms.	78	96	80	88	55	63	76	84	78	82	78	88	82	83	72	84
Total food gms.	324	324	356	360	270	268	314	316	328	330	222	222	350	356	304	304
Gain over control≠ gms.		18		8		8		8		4		10		1		12

* Diet Number 13

\# Diet Number 18

≠ Average gain over control 8.6 grams; gain required for least significant difference 4.3 grams.

TABLE 11.

THE VALUE OF GLUTAMIC ACID AS A SUPPLEMENT TO A CORN OIL MEAL DIET

	Pair 1		Pair 2		Pair 3		Pair 4		Pair 5		Pair 6		Pair 7		Pair 8	
	Con-trol*	Glu-tamic acid#	Con-trol	Glu-tamic acid	Con-trol	Glu-tamic acid	Con-trol	Glu-tamic acid	Con-trol	Glu-tamic acid	Con-trol	Glu-tamic acid	Con-trol	Glu-tamic acid	Con-trol	Glu-tamic acid
Initial Wt. gms.	122	122	122	122	120	120	120	120	120	120	118	118	116	116	116	116
Final Wt. gms.	202	204	263	202	200	204	192	194	196	203	199	199	199	203	186	186
Gain gms.	80	82	81	80	80	84	72	74	76	83	81	81	83	87	70	71
Total food gms.	345	345	354	356	352	352	308	309	214	214	341	340	326	224	304	304
Gain over control/ gms.		2		1		4		2		7		0		4		1

* Diet Number 13

\# Diet Number 19

/ Average gain over control 2.4 grams; gain required for least significant difference 2.1 grams.

TABLE 12.

THE VALUE OF LYSINE AS A SUPPLEMENT TO A CORN OIL MEAL DIET

	Pair 1		Pair 2		Pair 3		Pair 4		Pair 5		Pair 6		Pair 7		Pair 8	
	Control*	Lysine‡	Control	Lysine	Control	Lysine	Control	Lysine	Control	Lysine	Control	Lysine	Control	Lysine	Control	Lysine
Initial Wt. gms.	122	122	122	122	120	120	120	120	120	120	118	118	118	118	116	116
Final Wt. gms.	198	198	196	203	200	201	194	197	192	196	198	200	184	192	192	192
Gain gms.	76	76	74	81	80	81	74	77	72	76	80	82	66	74	76	76
Total food gms.	318	320	302	302	340	341	308	306	297	300	353	350	286	288	318	316
Gain over control† gms.		0		7		1		3		4		2		8		0

* Diet Number 13

‡ Diet Number 20

† Average gain over control 3.1 grams; gain required for least significant difference 2.3 grams.

Supplementation between corn oil meal and several common high protein feeds

The object of this investigation was to obtain information on the supplementation between corn oil meal and some of the common high protein feeds. Two experiments were conducted.

Experiment one; Procedure In this experiment, the supplementation between corn oil meal and pilchard fish meal, dry skimmilk, gelatin, cottonseed meal and blood meal was determined. The diets are described in Table 13 and the procedure was the same as that described under the general heading.

Experiment one; Results Because of a small difference in the protein level of the various rations, the results in this experiment are based on grams of gain per gram of protein consumed. The information summarized in Table 14 indicates that pilchard fish meal is most efficient in correcting the deficiency of the corn oil meal diet. Dry skimmilk and gelatin also proved to be fairly good supplements, while cottonseed meal and blood meal proved to be least valuable. The lots fed cottonseed meal and blood meal suffered a high mortality.

Representative chicks from lots receiving a protein supplement of corn oil meal blended with five high protein feeds are shown in Plate 2, numbers 1 through 5. Fifty percent of the supplementary protein was supplied by each product.

Experiment two; Procedure This experiment was conducted to obtain information on the supplementary effect between corn oil meal and yeast.

TABLE 13.

PERCENTAGE OF INGREDIENTS IN THE DIETS

Practical Protein Supplements for Corn Oil Meal*

Feeds[1]	Lot Numbers 21 21A	22 22A	23 23A	24 24A	25 25A
Ground yellow corn	20.00	13.50	15.50	5.25	11.00
Ground oats	25.00	25.00	25.00	25.00	25.00
Wheat bran	10.00	10.00	10.00	10.00	10.00
Wheat middlings	10.00	10.00	10.00	10.00	10.00
Alfalfa meal	5.00	5.00	5.00	5.00	5.00
Salt	1.00	1.00	1.00	1.00	1.00
Ground oyster shell	1.75	0.75	1.75	2.00	0.75
Steamed bone meal		2.00	0.50	0.50	2.00
Cod liver oil	0.25	0.25	0.25	0.25	0.25
Riboflavin supplement	3.00	7.00		7.00	7.00
Corn oil meal	19.00	22.00	22.00	26.00	24.00
Pilchard fish meal	5.00				
Gelatin		3.50			
Dry skimmilk			9.00		
Cotton seed meal				8.00	
Blood meal					4.00
Total	100.00	100.00	100.00	100.00	100.00

* Protein content ranged between 16.6 and 17.5 percent.

[1] 0.2 of an ounce of manganese sulphate added per 100 pounds of diet.

TABLE 14.

SUPPLEMENTATION BETWEEN CORN OIL MEAL AND FIVE HIGH PROTEIN FEEDS

Supplement	Lot*	Ave. gain in wt.		Protein consumed		Gain per gram protein consumed		Mortality
		By lots	By diets	By lots	By diets	By lots	By diets	By lots
	No.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	No.
50 percent[‡] corn oil meal plus 50 percent Pilchard fish meal	21	387		245		1.58		
	21a	432	410	277	261	1.56	1.57	1
50 percent corn oil meal plus 50 percent dry skimmilk	22	403		315		1.28		1
	22a	382	393	306	311	1.25	1.27	0
50 percent corn oil meal plus 50 percent gelatin	23	358		244		1.47		2
	23a	366	362	245	245	1.49	1.48	0
50 percent corn oil meal plus 50 percent cottonseed meal	24	300		270		1.11		1
	24a	344	322	301	286	1.14	1.13	9
50 percent corn oil meal plus 50 percent blood meal	25	300		253		1.19		8
	25a	309	305	261	257	1.18	1.19	5

* Twenty chicks started in each lot.
‡ Percent of supplementary protein furnished.

Plate 2. Representative chicks fed a cereal diet plus the following protein supplements:

Fig. 1 - Corn oil meal plus pilchard fish meal

Fig. 2 - Corn oil meal plus dry skimmilk

Fig. 3 - Corn oil meal plus gelatin

Fig. 4 - Corn oil meal plus cottonseed meal

Fig. 5 - Corn oil meal plus blood meal

Each product furnished fifty percent of the supplementary protein.

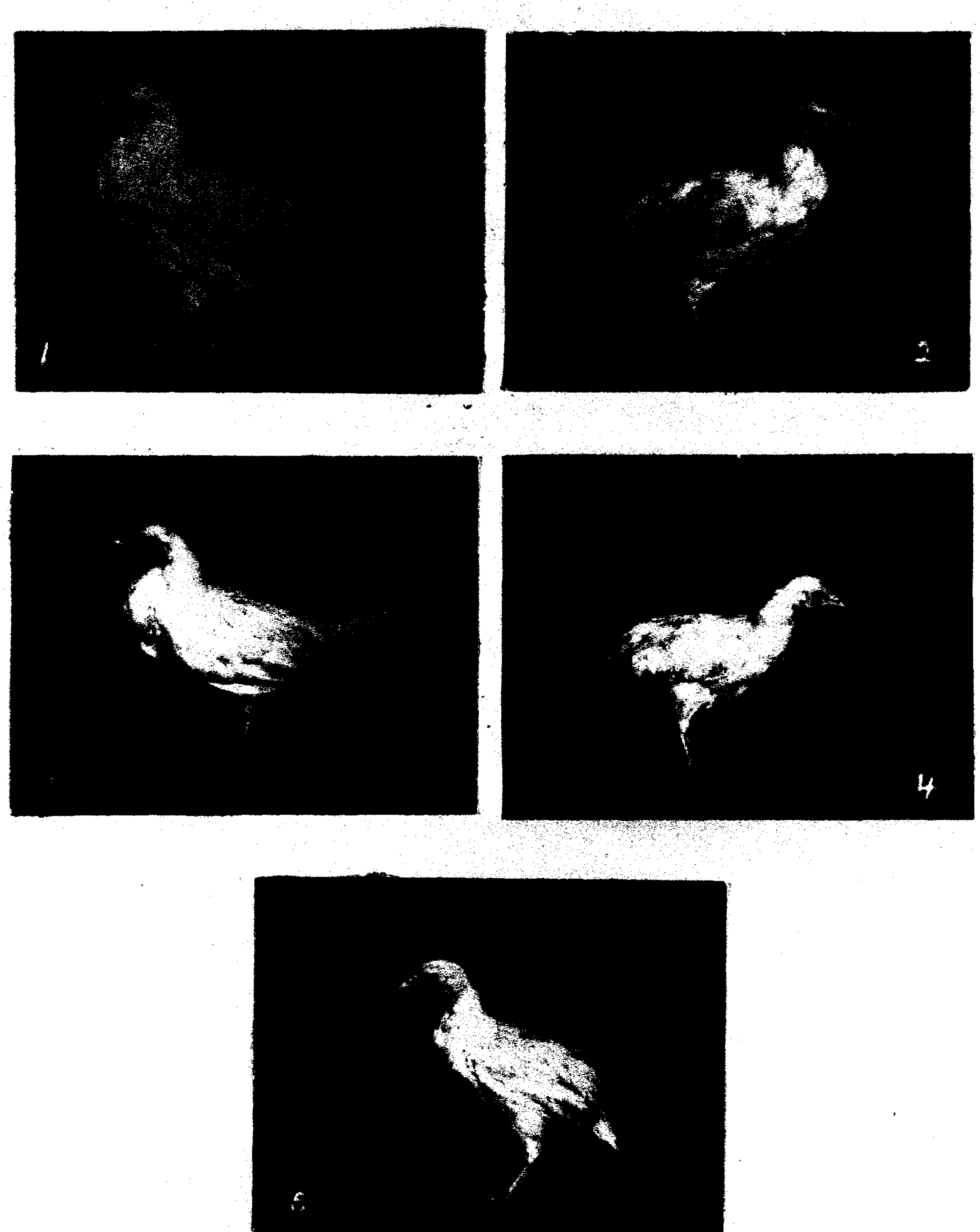

Plate 2.

The method of procedure developed by Heiman, et al. (11) was followed. A large number of day-old cockerels were fed the depletion diet described in Table 15 for a two week period. Then the experimental lots were made up and fed the test diets described in the same table for the next two weeks. The selection of the cockerels for the experimental lots was randomized as described under the group feeding method. Weights and feed consumption data were recorded at weekly intervals.

Experiment two; Results The value of yeast in varying amounts as a supplement to a corn oil meal diet is summarized in Table 16.

An examination of this table shows that the lots receiving yeast or any combination of yeast and corn oil meal consumed more feed and gained more than the lots receiving corn oil meal as the only protein supplement. The lots receiving yeast as the sole protein supplement utilized their feed most efficiently. However, an analysis of covariance test revealed that after the gains were adjusted to a common food intake basis they did not differ significantly. This suggests that the nutritive values of the unsupplemented corn oil meal diets cited in Tables 3 and 16 are not seriously limited by their riboflavin content.

Since this experiment was conducted a partial analysis of the amino acid content of the yeast used has been made available. This analysis shows that yeast contains less than 0.5 percent cystine, calculated on a moisture-free basis. No information is available on the methionine content of the yeast fed. However, if the methionine content of this product was also low, the lack of supplementation between corn oil meal and yeast may be partially

TABLE 15.

PERCENTAGE OF INGREDIENTS IN THE DIETS

Feeding Yeast as a Supplement for Corn Oil Meal*

Feeds#	Lot Numbers					
	Cereal Basal	26 26A	27 27A	28/ 28A	29 29A	30 30A
Ground yellow corn	16.67					
Ground oats	40.00					
Wheat bran	16.67					
Wheat middlings	16.67					
Alfalfa meal	8.33					
Salt	1.66					
Cereal basal		62.40	62.40	62.40	62.40	62.40
Corn oil meal		13.00		11.70	9.80	6.50
Feed yeast			7.20	0.74	1.80	3.60
Sugar		22.10	26.80	22.55	23.18	24.14
Cod liver oil		0.25	0.25	0.25	0.25	0.25
Calcium carbonate		0.95	1.40	0.95	1.10	1.45
Tri-calcium phosphate		1.30	.85	1.30	1.20	1.10
Fiber			1.10	0.11	0.27	0.56
Total	100.00	100.00	100.00	100.00	100.00	100.00

* All test diets adjusted to 11 percent protein.

\# 0.2 of an ounce of manganese sulphate added per 100 pounds of diet.

/ The ratio of supplementary protein furnished by corn oil meal and yeast respectively was as follows: Diet 28, 90-10; Diet 29, 75-25 and Diet 30, 50-50.

TABLE 16.

THE VALUE OF YEAST AS A SUPPLEMENT TO A CORN OIL MEAL DIET

Supplement	Lot	Ave. gain in wt.		Ave. feed consumption		Feed efficiency	
		By lots	By diets	By lots	By diets	By lots	By diets
	No.	Gms.	Gms.	Gms.	Gms.		
Corn oil meal	26	24		172		7.2	
	26a	25	24.5	159	166	6.4	6.8
Yeast	27	39		191		4.9	
	27a	42	40.5	217	204	5.2	5.1
90* percent corn oil meal plus 10 percent yeast	28	27				6.4	
	28a	39	30.0	265	219	6.8	6.6
75 percent corn oil meal plus 25 percent yeast	29	36		221		6.1	
	29a	49	42.5	232	227	4.7	5.4
50 percent corn oil meal plus 50 percent yeast	30	35		195		5.6	
	30a	43	39.0	208	202	4.8	5.2

* Percent of supplementary protein furnished.

due to a deficiency of the sulphur-carrying amino acids.

From Table 16 it is interesting to note that the feed efficiency varies directly with the amount of yeast compounded in the diet. No mortality occurred in this experiment.

The nutritive value of sodium sulfide treated feathers

Procedure Since previous experiments showed that the corn oil meal diet employed was deficient in cystine, and since it is common knowledge that feathers contain a large amount of this amino acid, it seemed advisable to include feather proteins in the corn oil meal diet. Thus an investigation was planned to determine the nutritive value of sodium sulfide treated feathers when fed as the sole protein supplement and when fed in combination with corn oil meal. Three trials were conducted. The diets are described in Table 17 and the procedure was the same as that described under the general heading.

The preparation of the feathers was as follows: One pound of sodium sulfide and 16 grams of sodium hydroxide pellets were dissolved in approximately 6 liters of water, 700 grams of feathers were added and the mixture allowed to stand, with occasional stirring, for 24 hours. During this time the feathers were completely dissolved. Dilute hydrochloric acid was then added until neutral to litmus paper. The residue was separated from the liquid by filtering through a large Büchner filter, washed, and dried at a temperature of 100°F. The dried residue was ground with a mortar and pestle.

TABLE 17.

PERCENTAGE OF INGREDIENTS IN THE DIETS

Sodium Sulphide Treated Feathers as a Supplement for Corn Oil Meal

Feeds*	Trial 1# & 2#				Trial 3/		
	Lot Numbers				Lot Numbers		
	31 31A	32 32A	33 33A	Cereal Basal	34	35	36
Ground yellow corn		19.00	36.09	16.67			
Ground oats	23.34	25.00	25.00	40.00			
Wheat bran	10.00	10.00	10.00	16.67			
Wheat middlings	10.00	10.00	10.00	16.67			
Alfalfa meal	5.00	5.00	5.00	8.33			
Salt	1.00	1.00	1.00	1.66			
Cereal basal					60.00	60.00	60.00
Corn oil meal	46.00	20.34			36.00	18.00	
Na_2S treated feathers		5.00	8.75			5.50	11.00
Corn starch						11.00	22.00
Riboflavin supplement	0.66	0.66	0.66		0.66	0.66	0.66
Cod liver oil	0.25	0.25	0.25		0.25	0.25	0.25
Ground oyster shell	0.25	0.25	0.25		0.25	0.25	0.25
Steamed bone meal	3.50	3.50	3.00		2.84	2.84	2.84
Fiber						1.50	3.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* 0.2 of an ounce of manganese sulphate added per 100 pounds of diet.

\# Adjusted to 16 percent protein.

/ Adjusted to 15 percent protein.

<u>Results</u> The results of three trials in which sodium sulfide treated feathers were fed are summarized in Tables 18 and 19.

No statistical analysis was made because of the high mortality of some lots. Table 18 shows that the chicks fed the corn oil meal sodium sulfide feather protein blend gained over 40 percent more, on approximately 25 percent more feed, than the chicks fed each product alone. This gain is undoubtedly significant.

In the third trial the lot fed sodium sulfide treated feathers suffered a high mortality and the gain was considerably below that obtained in trials one and two. Two explanations seem possible. In the first and second trials the protein level was fixed by adjusting the amount of corn meal and feather protein; making it necessary to include only 8.75 percent of the latter product in the diet. In the third trial corn starch was used to adjust the protein level which necessitated the inclusion of 11.00 percent feather protein in the diet. This additional amount of feather protein possibly made the ration less palatable which resulted in decreased growth and high mortality. However, the evidence seems to indicate that the results obtained in the third trial were due to the processing of the feathers. Possibly enough sodium sulfide remained in the feathers to produce a toxic effect.

The results obtained from feeding the corn oil meal diets show that the rate of gain and feed efficiency increased markedly and mortality decreased between the 16 and 15 percent protein level. This, no doubt, was due to the fact that different products were used to adjust the protein

TABLE 18.

THE VALUE OF SODIUM SULFIDE TREATED FEATHERS, CORN OIL MEAL, AND A COMBINATION OF THESE PRODUCTS AS A PROTEIN SUPPLEMENT IN THE CHICK DIET

Supplement	Protein level	Lot	Trial	Ave. gain in weight		Ave. feed consumption		Feed efficiency		Mortality
				By lot	By diet	By lot	By diet	By lot	By diet	By lots
	%	No.	No.	Gms.	Gms.	Gms.	Gms.			%
Sodium sulfide	16	27	1	187		897		4.8		0
treated feathers	16	30	2	197	192	910	904	4.6	4.7	33
	15	33	3	153		978		6.4		80
50 percent* sodium										
sulfide treated	16	28	1	368		1464		4.0		0
feathers plus 50	16	31	2	305	337	1112	1298	3.6	3.8	0
percent corn oil	15	34	3	240		1068		4.4		7
meal										
	16	29	1	93		595		6.4		43
Corn oil meal	16	32	2	120	107	846	722	7.1	6.8	73
	15	35	3	338		1445		4.3		13

* Percent of supplementary protein furnished.

TABLE 19.

THE VALUE OF SODIUM SULFIDE TREATED FEATHERS, CORN OIL MEAL, AND A COMBINATION OF THESE PRODUCTS AS A PROTEIN SUPPLEMENT IN THE RAT DIET

Supplement	Protein Level	Lot	Trial	Ave. gain in weight		Ave. feed consumption		Feed efficiency		Mortality
				By lot	By diet	By lot	By diet	By lot	By diet	By lot
	%	No.	No.	Gms.	Gms.	Gms.	Gms.			%
Sodium sulfide	16	30a	1	125		680		5.4		0
treated feathers	15	33a	2	153	139	926	803	6.1	5.7	0
50 percent* sulfide										
treated feathers plus	16	31a	1	113		725		6.4		10
50 percent corn oil	15	34a	2	135	124	824	775	6.1	6.2	0
meal										
	16	32a	1	90		600		6.7		50
Corn oil meal	15	35a	2	125	108	772	686	6.2	6.4	10

* Percent of supplementary protein furnished.

level, as explained above.

Plate 3, numbers 1 through 3, shows representive chicks from lots in trial one, which received a protein supplement of sodium sulfide treated feathers, corn oil meal and a combination of these products.

The above mentioned products, as shown in Table 19, did not have the same nutritive value for rats as chicks. Rats fed a diet in which sodium sulfide treated feathers served as the sole protein supplement grew faster than those fed corn oil meal or a combination of corn oil meal and feather protein. This again suggests that the amino acid requirements of the chick and rat are not the same.

The same sample of feathers was fed to rats in trial 2 (Table 19) as to chicks in trial 3 (Table 18). It is interesting to note that, for the rat, this sample of feathers did not decrease rate of growth or increase mortality as in the case of the chick.

The effect of autoclaving on the nutritive value of feather protein

Procedure It has been demonstrated that sodium sulfide feathers can be utilized by the chick or rat. However, since it would not be practical to treat feathers with sodium sulfide for large scale work, and since results from an exploratory experiment suggested that the application of heat enhanced the nutritive value of feather protein it seemed advisable to obtain information on the effect of autoclaving on the nutritive value of feathers.

Plate 3. - Fig. 1 - Eight week old chick fed a cereal diet supplemented with sodium sulfide treated feathers. Note poor development.

Fig. 2 - Eight week old chick fed a cereal diet supplemented with corn oil meal. Note poor development

Fig. 3 - Eight week old chick fed a cereal diet supplemented with a corn oil meal-sodium sulfide treated feather protein blend. Each product supplied 50 percent of the supplementary protein.

Plate 3.

The feathers were prepared by placing them in shallow containers inside a large autoclave and heating the various lots of feathers for 2, 4, 6 and 8 hours respectively. Fifteen pounds pressure was maintained for the 2 and 4 hour treatments and 20 pounds for the 6 and 8 hour treatments. The feathers were dried by placing a thin layer on a wire platform beneath an electric chick brooder. The temperature under the brooder was maintained at 100°F. A Wiley mill, equipped with a screen containing perforations 2 millimeters in diameter, was used to grind the feathers. The procedure was the same as that described under the general heading. The diets fed in this experiment are described in Table 20.

Results The effect of autoclaving for various periods at different pressures on the nutritive value of feathers is summarized in Table 21.

Examination of this table shows that the lots receiving untreated feathers consumed the largest amount of feed and made the largest gain but utilized the feed less efficiently. Gain in body weight and feed efficiency varied inversely with the amount of heat applied. However, an analysis of covariance test showed that, after the gain had been adjusted to a common food intake basis, the gain of the chicks receiving the autoclaved feathers was not significantly below that of the chicks receiving the untreated feathers.

The higher feed consumption of the lots receiving the untreated feathers is possibly due to the fact that the untreated feathers were very light and fluffy and easily carried away by air currents.

TABLE 20.

PERCENTAGE OF INGREDIENTS IN THE DIETS

The Effect of Autoclaving on the Nutritive Value of Feather Protein/

Feeds*	Lot Numbers		
	Cereal Basal	38** 37A	38" 38A-I
Ground yellow corn	16.67		
Ground oats	40.00		
Wheat bran	16.67		
Wheat middlings	16.67		
Alfalfa meal	8.33		
Salt	1.66		
Cereal basal		71.50	71.50
Feather protein			8.60
Sugar		25.69	17.19
Riboflavin supplement		0.66	0.66
Cod liver oil		0.25	0.25
Calcium carbonate		0.50	0.50
Tri-calcium phosphate		1.40	1.30
Total	100.00	100.00	100.00

* 0.2 of an ounce of manganese sulphate added per 100 pounds of diet.

** Negative control diet, adjusted to 8 percent protein.

" Adjusted to 15 percent protein.

/ The heat treatment was as follows:-
Diet 38 and 38A - treatment
Diet 38B and 38C- autoclaved 2 hours at 15 pounds pressure.
Diet 38D and 38E- autoclaved 4 hours at 15 pounds pressure.
Diet 38F and 38G- autoclaved 6 hours at 20 pounds pressure.
Diet 38H and 38I- autoclaved 8 hours at 20 pounds pressure.

TABLE 21.

THE EFFECT OF AUTOCLAVING ON THE NUTRITIVE VALUE OF FEATHER PROTEIN

Supplement	Lot*	Ave. gain in wt.		Ave. feed consumption		Feed efficiency		Mortality
		By lots	By diets	By lots	By diets	By lots	By diets	By diets
	No.	Gms.	Gms.	Gms.	Gms.			No.
	37	116	121.0	692		6.0		
None	37a	126		771	731	6.1	6.0	5
Untreated feathers	38	203		1403		6.9		
	38a	219	211.0	1245	1324	5.7	6.3	4
Feathers autoclaved 2 hrs. at 15# pressure	38b	204		982		4.8		
	38c	203	203.5	926	954	4.6	4.7	0
Feathers autoclaved 4 hrs. at 15# pressure	38d	198		1008		5.1		
	38e	197	197.5	915	961	4.6	4.9	0
Feathers autoclaved 6 hrs. at 20# pressure	38f	206		910		4.4		
	38g	158	182.0	895	902	5.7	5.0	5
Feathers autoclaved 8 hrs. at 20# pressure	38h	184		954		5.2		
	38i	188	186.0	945	949	5.0	5.1	1

* 20 chicks started in each lot.

Chick number 1, Plate 4, is a representative chick fed an 8 percent protein cereal diet. Number 2 is a representative chick fed an 8 percent protein cereal diet plus a sufficient quantity of ground feathers to supply 7 percent crude protein. The latter diet differed from the former one in that it contained 8.6 percent ground feathers which replaced an equivalent amount of sugar.

The results of one nitrogen balance trial, in which ten chicks were used, showed that the chicks fed a diet containing ground feathers retained 9.59 percent more dietary nitrogen than chicks fed the cereal diet. The supplementation between the cereal diet and the feathers undoubtedly increased the quantity of the amino acid (or acids) limiting the utilization of the protein which evidently accounts for this increased retention of nitrogen. This seems to be a partial explanation of the increased growth resulting from feeding supplementary ground feathers, but inadequate for a complete explanation. Additional research seems necessary to arrive at a more complete explanation.

Three chicks fed the diet containing ground feathers developed necrosis of the lower mandible as shown in Plate 4, number 3. The ground feathers, rather than the other ingredients of the diet, seemed to be responsible for this condition.

Plate 4. - Fig. 1 - Eight week old chick fed an 8 percent crude protein cereal diet. Note poor growth and feathering.

Fig. 2 - Eight week old chick fed an 8 percent crude protein cereal diet supplemented with a sufficient quantity of ground feathers to supply 7 percent crude protein. Note good feathering.

Fig. 3 - Eight week old chick showing severe necrosis of the beak.

Plate 4.

DISCUSSION

The results of these studies led to the conclusion that chicks fed a diet containing large quantities of corn oil meal grew at a very slow rate, utilized their feed very inefficiently and suffered a high mortality. The evidence seems to indicate that this was mainly due to the quality of protein in corn oil meal, but when over 30 percent of this product was compounded in the diet, palatability became a factor. The diet containing 45 percent corn oil meal was consumed very sparingly by the chicks. Although feed was available at all times they appeared to be starving. The rats consumed the diets containing large quantities of corn oil meal more readily than the chicks.

Routh (23) reported that feed consumption increased very rapidly when a nutritionally deficient diet was replaced by an adequate one, and Maynard (15) stated, "A frequent effect of a nutritionally deficient ration is to decrease food consumption." This seems to explain the difference in feed consumption of the chicks fed the control diets and those fed the corn oil meal diets containing less than 30 percent corn oil meal. (Plate 1.)

The Nebraska workers obtained a satisfactory growth when as much as 20 percent freshly manufactured corn oil meal was compounded into the chick diet. The growth obtained in the present investigation when a similar amount of this product was fed as the sole source of supplementary protein was somewhat lower. However, this can be explained by the fact that in the Nebraska investigation corn oil meal replaced cereal grains in the diet while in the present investigation it replaced all of the high protein feeds.

The addition of methionine to the corn oil meal diet used would, undoubtedly, produce results equal to cystine since Hayward and Hafner (8), Jackson and Block (12), Womack et al. (28) and others have sufficiently demonstrated that methionine can completely replace cystine in the diet of the chick or rat. Since they also demonstrated that cystine cannot completely replace methionine, the addition of the latter amino acid may have produced faster growth than that produced from the addition of cystine.

Almquist (1) reported that the chick requires glycine and probably lysine in the diet for optimum growth. The results obtained in this investigation confirm his findings.

The corn oil meal diet fed to rats evidently contained a sufficient quantity of the sulphur-carrying amino acids to support optimum growth, since results of one experiment showed that the addition of 1 percent cystine to this diet did not increase the rate of gain. Since feathers contain a high percentage of cystine this partly explains the results obtained when chicks and rats were fed the corn oil meal-sodium sulfide treated feather protein blend. The markedly different results obtained for these two species when fed a corn oil meal diet supplemented with cystine or cystine rich protein feeds demonstrate that the amino acid requirements of the rat are not identical with those of chicks.

The riboflavin[1/] content, as determined by the Snell and Strong method, in five samples of the corn oil meal used, ranged from four to six micrograms of riboflavin per gram of product. This was a sufficient quantity to increase the riboflavin content of the corn oil meal diets fed to approximately 1000 micrograms per pound of diet.

Routh and Lewis (21) reported that the prolonged grinding of wool rendered it digestible by pepsin and trypsin, in vitro. Kühne (13) observed that the keratin of hair was made digestible by pepsin, in vitro, when the surface area was increased by mechanical means, and Biossevain (2) found that the grinding of gelatin caused a degradation similar to acid hydrolysis. From the results obtained by these investigators with wool, hair and gelatin, in vitro, it seems quite possible that the proteins of ground feathers are acted upon by pepsin and trypsin in vivo.

When the feathers were autoclaved for more than 4 hours, at 15 pounds pressure, they became less bulky and had approximately the same weight per unit volume as ground oats. The diet containing untreated ground feathers was very bulky, but the chicks consumed it as readily as the diets containing autoclaved feathers. It was interesting to note that the chicks fed the untreated ground feather diet consumed more water than the chicks fed the diets containing autoclaved feathers.

1/ Riboflavin analysis made through the courtesy of Mr. M. Rhian, Asst. Chemist, Agr. Exp. Sta., State College of Washington, Pullman, Wash.

CONCLUSIONS

1. Chicks and rats fed a cereal diet supplemented with large quantities of corn oil meal (over 30 percent) grew at a very slow rate, utilized their feed inefficiently and suffered a high mortality.
2. The inclusion of up to 30 percent corn oil meal in the chick diet did not affect the palatability of the feed.
3. Chicks fed diets containing up to 20 percent corn oil meal grew at a slower rate than those fed a proven diet. This difference increased very rapidly when greater quantities of corn oil meal were fed.
4. The addition of 0.6 percent cystine or lysine to the cereal chick diet supplemented with 30 percent corn oil meal resulted in a significant increase in growth.
5. Pilchard fish meal was most efficient in correcting the deficiency of the corn oil meal diets. This was followed by dry skimmilk, gelatin, cottonseed meal and blood meal respectively.
6. Corn oil meal, sodium sulfide treated feathers or combinations of these products did not have the same nutritive value for chicks and rats, demonstrating a difference in the amino acid requirements for these species.
7. The addition of feathers to a cereal diet resulted in a rate of growth significantly greater than that produced by the cereal diet when fed

to chicks or rats.

8. The nutritive value of feathers is not enhanced by autoclaving.

SUMMARY

Several experiments were conducted with White Leghorn chicks and with rats to determine the nutritive value of corn oil meal and feather protein. Rate of body gain, feed efficiency and mortality were used to measure the nutritive value of these products.

When chicks were fed a cereal diet supplemented with the proteins of corn oil meal only, the rate of body gain and feed efficiency were considerably below, and mortality above, that of the chicks fed the cereal diet supplemented with proven protein supplements. The inclusion of over 30 percent corn oil meal in the diet of the chick or rat resulted in a very slow rate of growth, poor feed efficiency and high mortality. This appeared to be due to the combined effects of poor palatability and the relatively low nutritive value of this product.

The results of two trials in which the corn oil meal diet was supplemented with various amino acids showed that the addition of 0.6 percent cystine or lysine caused a significant increase in rate of growth. The addition of glycine and glutamic acid caused a slight increase in growth while the addition of tryptophane, arginine and histidine did not increase rate of growth.

Of several common protein feeds used, pilchard fish meal was most efficient in overcoming the deficiencies of the proteins found in corn oil meal. This was followed by dry skimmilk, gelatin, cottonseed meal and

blood meal respectively.

Chicks fed a cereal diet supplemented with sodium-sulfide treated feathers or corn oil meal, as the sole source of protein, grew at essentially the same rate and utilized their feed with approximately the same efficiency. When each of these products furnished 50 percent of the supplementary protein the rate of growth increased markedly and feed efficiency improved.

However, when rats were fed a cereal diet supplemented with the proteins of corn oil meal, or a combination of corn oil meal and sodium sulfide treated feather protein, the growth was less than when the latter product furnished the entire amount of supplementary protein.

When chicks were fed an 8 percent crude protein cereal diet supplemented with a sufficient quantity of finely ground feathers to supply 7 percent crude protein the rate of growth was much faster than that of the controls fed the cereal diet only.

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